Satellite Remote Sensing applications for Landslide Hazard Monitoring

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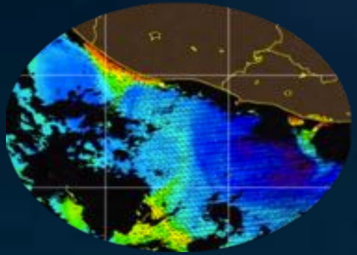
Outline

- Background on SERVIR
- NASA's work in global landslide hazard monitoring
- Country case briefs on landslide monitoring using remote sensing
- Case study on relationship between fires and landslides in Nepal
- CEOS Landslide Disaster Working Group Pilot
- Areas for collaboration

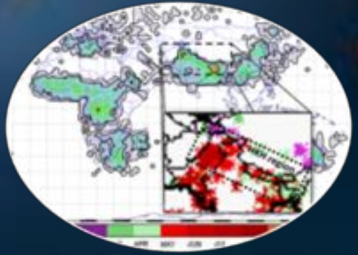
SERVIR is a joint development initiative of NASA and USAID, working in partnership with leading regional organizations around the globe, to help developing countries use information provided by Earth observing satellites and geospatial technologies to address Food Security, Water and Disasters, Weather and Climate, and Land Use/Land Cover Change.



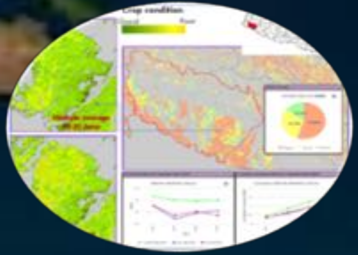
Preventing seafood-borne illnesses in Central America by mapping harmful microalgae

Helping herders and farmers in West Africa by detecting ephemeral water bodies

Conserving forests in eastern and southern Africa by mapping land cover and land use change



Protecting lives in South/Southeast Asia by monitoring and forecasting intense thunderstorms



Supporting food security in Nepal by monitoring agricultural drought

adpc
ICIMOD
USAID
FROM THE AMERICAN PEOPLE
NASA

The Current SERVIR Hub Network

SERVIR's approach to disaster risk reduction

Water and Water-related Disasters Thematic Service Area of SERVIR

✓ Shifting from product creation to **service design and delivery**

✓ Improving **scientific and technical rigor** of services through external "Technical Assessment Groups"

✓ Bringing **more innovative and appropriate science** from the US
  - 118 US institutions across all thematic service areas

✓ Enhancing **collaboration** across SERVIR hubs

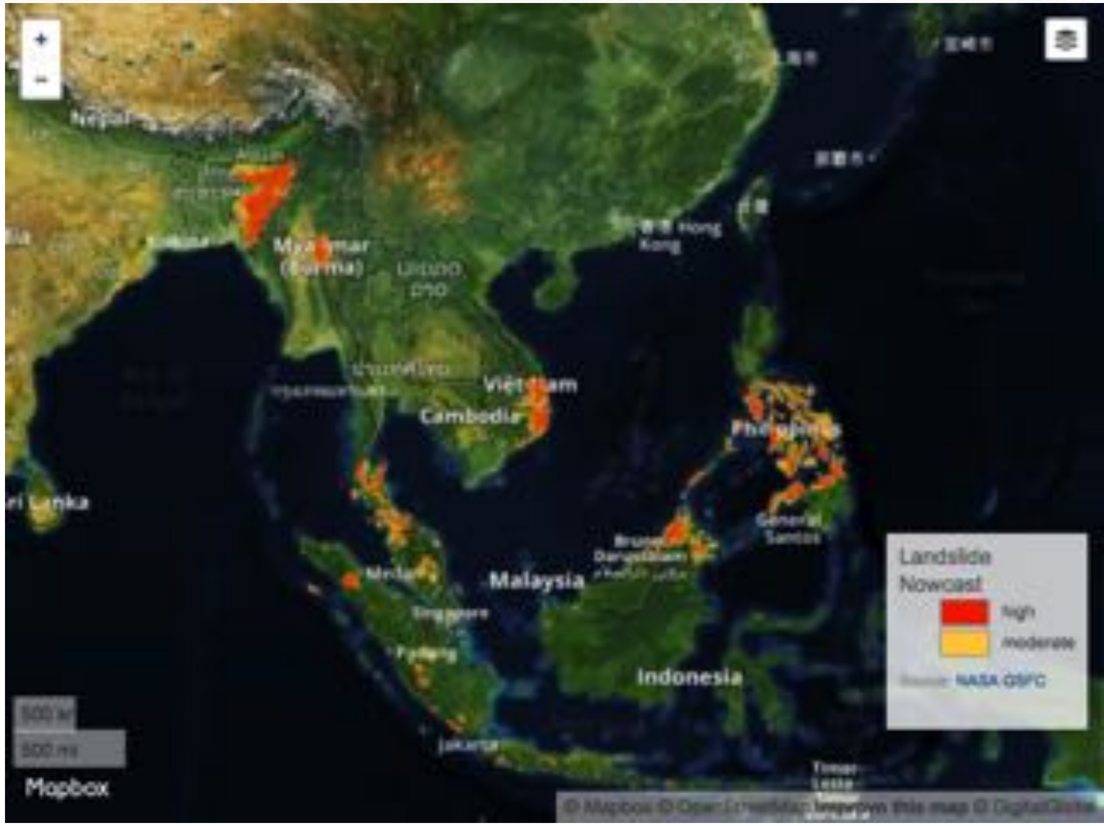
SERVIR's approach to disaster risk reduction

Role of SERVIR in NASA Earth Science Disasters Program

- ✓ Match needs on the ground with technical expertise that Earth scientists can provide
- ✓ Build capacity of agencies around the world to use Earth observation information
- ✓ Provide feedback to NASA on the utility of science products for disaster management
- ✓ Provide input from the international "applications" community perspective

NASA's work in global landslide hazard monitoring

- The global Landslide Hazard Assessment for Situational Awareness (LHASA) model is developed to provide situational awareness of landslide hazards for a wide range of users. [1]
    - Considers weighted satellite-derived precipitation (GPM IMERG), roads, deforestation and burning, tectonic faults, bedrock conditions, and slope
    - "Global Landslide Nowcast" is updated daily
- NASA Global landslide catalog [2]
    - developed with the goal of identifying rainfall-triggered landslide events around the world, regardless of size, impacts or location



https://pmm.nasa.gov/applications/global-landslide-model

[1] Stanley, T., and D. B. Kirschbaum (2017), A heuristic approach to global landslide susceptibility mapping, Nat. Hazards, 1–20, doi:10.1007/s11069-017-2757-y. http://link.springer.com/article/10.1007%2Fs11069-017-2757-y

[2] Kirschbaum, D. B., Adler, R., Hong, Y., Hill, S., & Lerner-Lam, A. (2010). A global landslide catalog for hazard applications: method, results, and limitations. Natural Hazards, 52(3), 561–575. doi:10.1007/s11069-009-9401-4. https://data.nasa.gov/Earth-Science/Global-Landslide-Catalog-Export/dd9e-wu2v

Case briefs

1. 2009 Landslides in El Salvador, and follow-on hazards analysis
2. 2015 Gorkha earthquake in Nepal
3. Applied research for better understanding of landslide hazards in Rwanda

Case brief: 2009 El Salvador landslides

- Convergence of a tropical storm in the Pacific and a low pressure system in the Atlantic led to extremely intense and prolonged rainfall, and resulting floods and landslides

Data from disconnected decision support tools are difficult to assimilate and can provide conflicting information

Mass wasting susceptibility

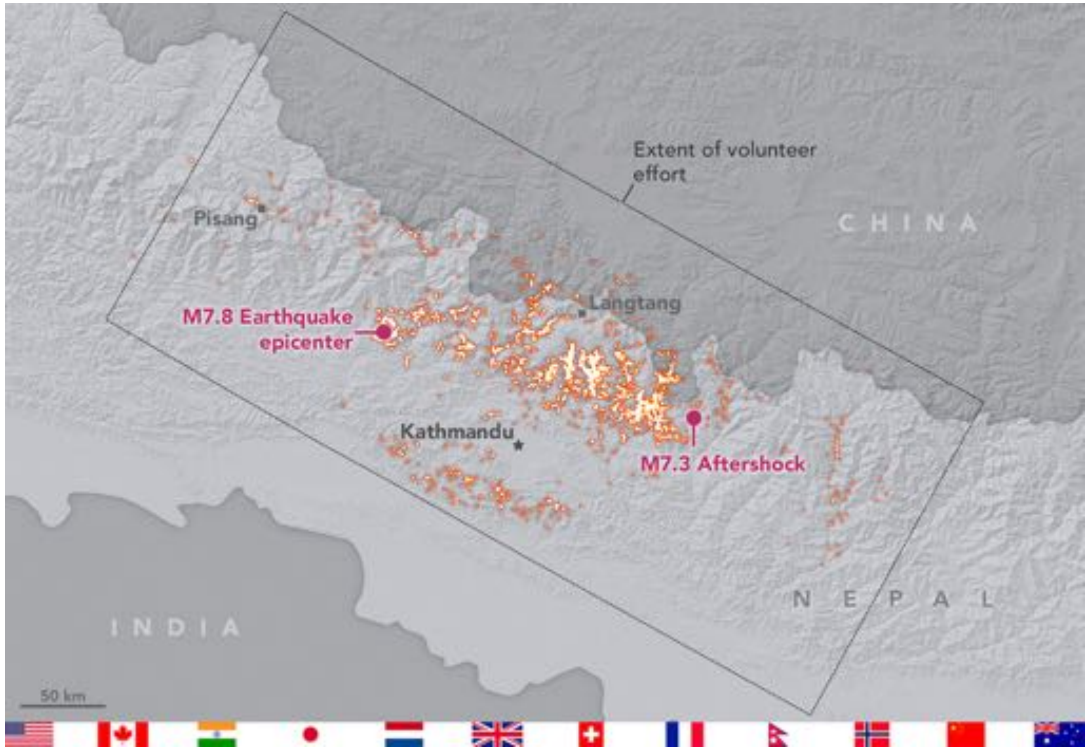
Lahar inundation zone

(Anderson, 2013)

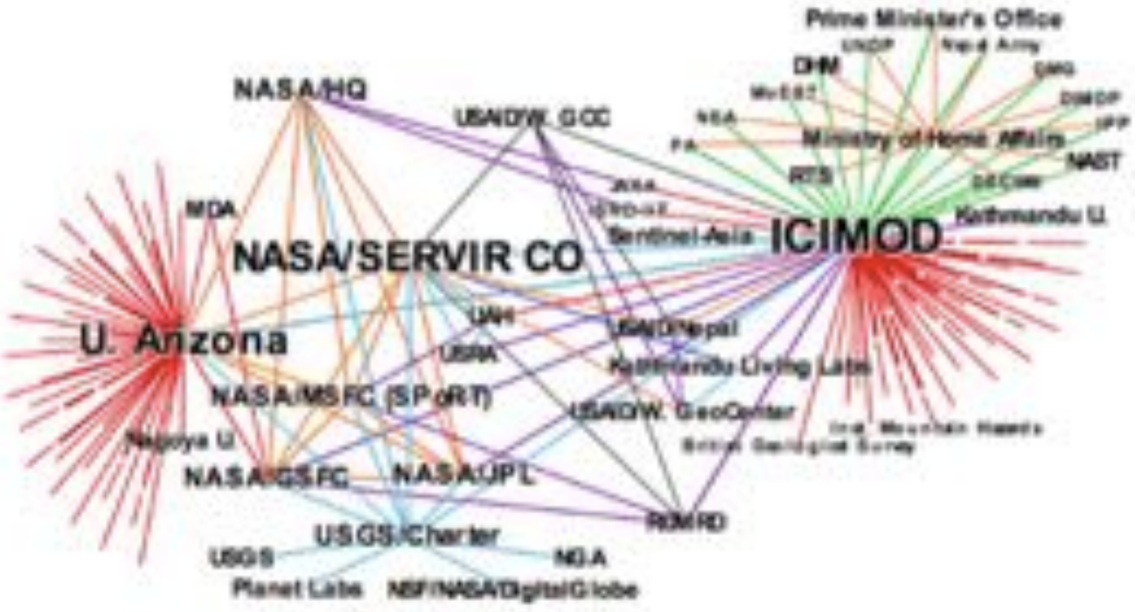
- Charter activation involving rapid response mapping
- Value-added products supported reconstruction plan
- Realized that follow-on applied research was needed

Case brief: 2015 Gorkha earthquake in Nepal

- 4312 landslides identified from 10 satellites: fewer landslides than expected for an earthquake of this magnitude, possibly due to much less shaking at the surface (Kargel et al. 2016)
- Network analysis showing volunteer scientists & analysts (red) and connections with user / decision making agencies (green) (Schumann et al. 2016)

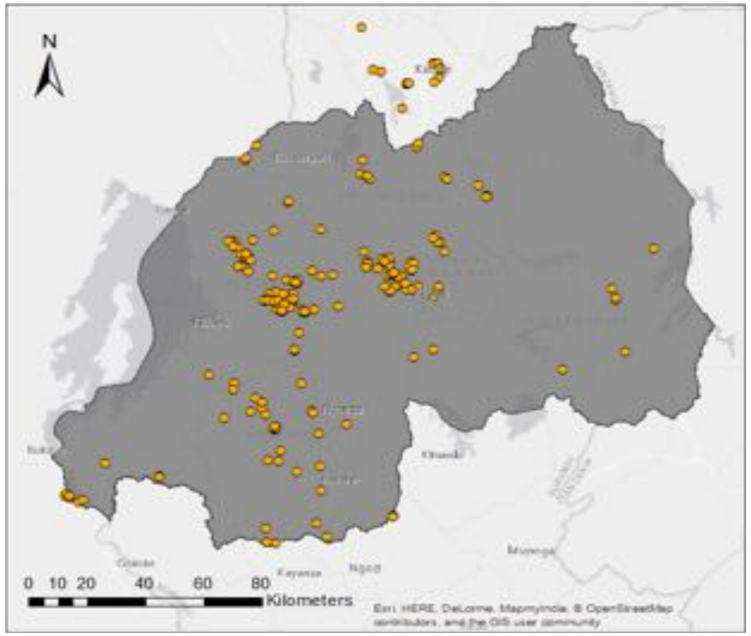


NASA / GSFC

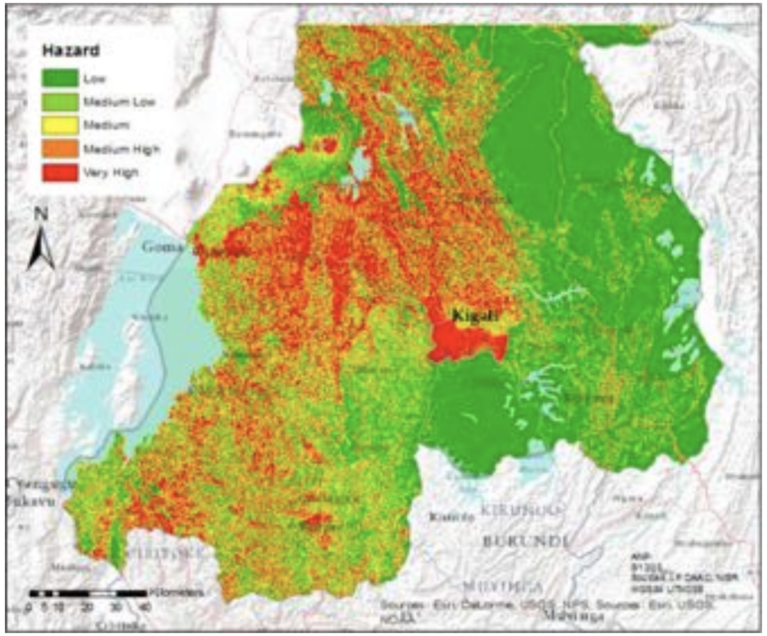


Case brief: Applied research for better understanding of landslide hazards in Rwanda

- From US Geological Survey, we need to know 4 things about landslides
  1. When will they happen?
  2. Where will they start?
  3. Where will the go?
  4. What could be affected?



254 landslide events identified through visual interpretation of high resolution images in Google Earth



Preliminary hazard map derived through logistic regression testing (Piller and Anderson 2015)

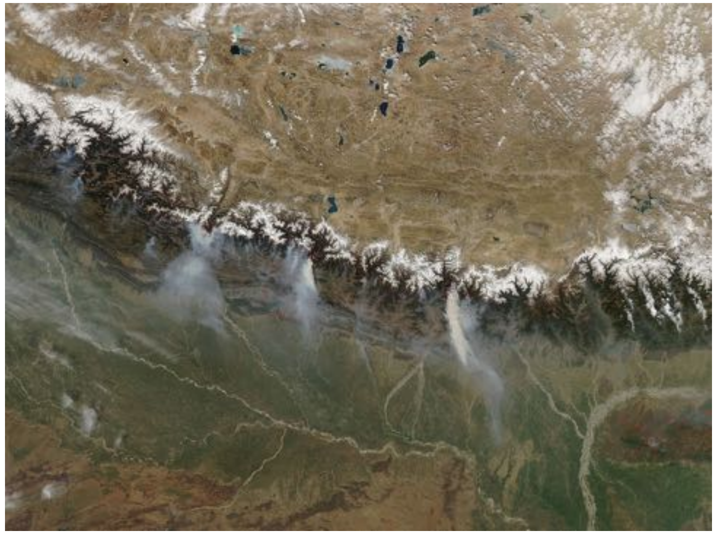
Possible next steps: Consider new ways to collect crowd-sourced data (e.g., Space Apps Challenge)

Case study: Nepal fire-landslide relationship

Overarching question: Can we detect any relationships between fires and landslides in Nepal, as seen from the satellite remote sensing perspective?

- Justification
    - Post-fire landslide probability is often considered in U.S. Great Basin
    - Burned Area Emergency Response (BAER) teams assess post fire threats to lives, property, and resources
    - Apparent lack of research into fire/landslide linkages in Nepal

- Fires in Nepal
    - Prolonged dry seasons and lower winter precipitation in Nepal have increased wildfire incidences
    - Fire is a major cause of forest degradation in Nepal

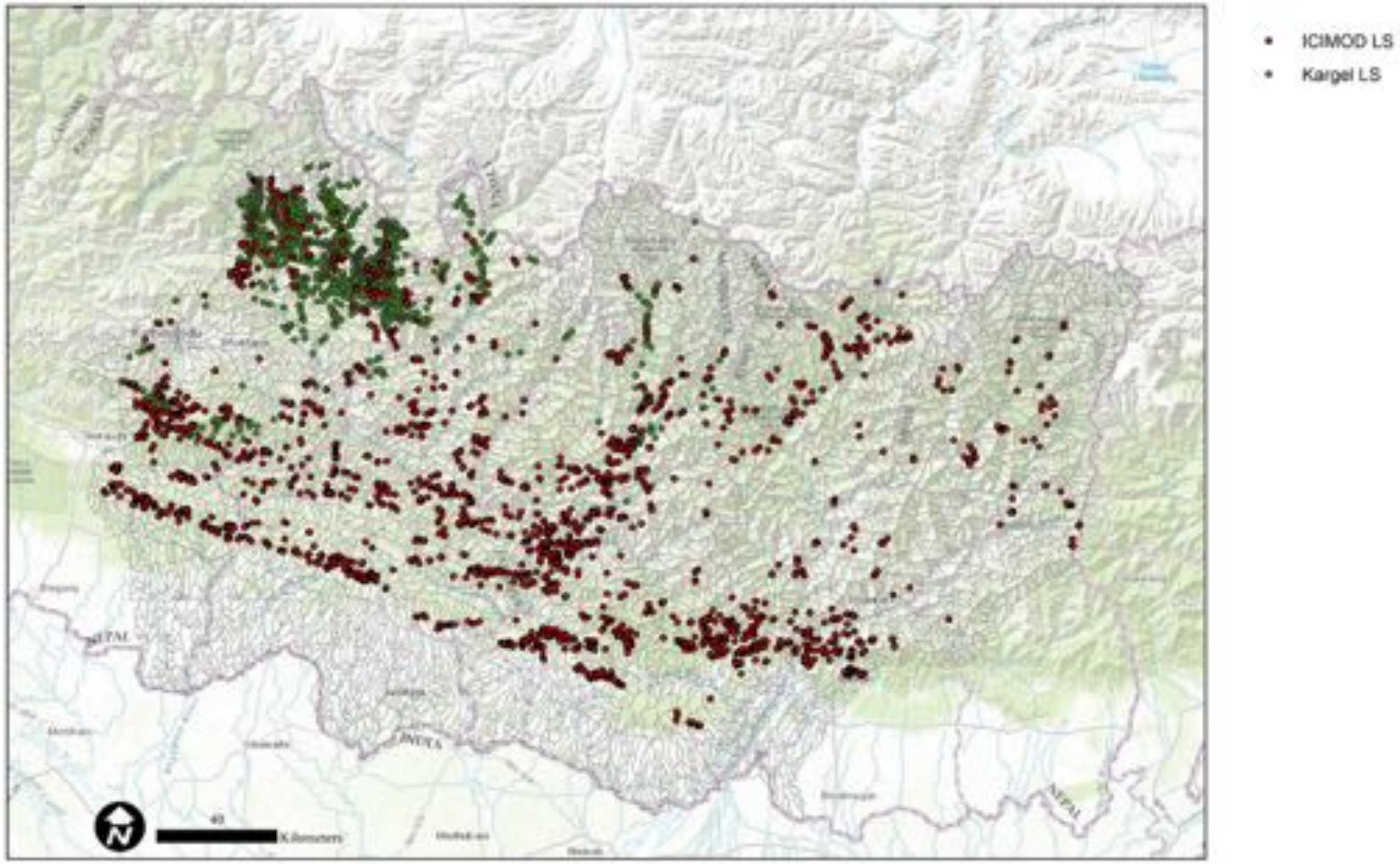


NASA Earth Observatory (2016)

Case study: Nepal fire-landslide relationship

- Study areas:
  - Koshi Basin, Nepal – rainfall-triggered landslides (ICIMOD database)
  - Gorkha earthquake affected area in Nepal (Kargel et al 2016)

- Research questions
  - Is there a relationship between **fire frequency/severity** and **landslide occurrence**?
  - How does the relationship change when considering **rainfall-** vs. **earthquake-triggered** landslides?



Case study: Nepal fire-landslide relationship

- Approach
  - Test response of **rainfall**-triggered landslides (ICIMOD / Koshi basin) and **earthquake**-triggered landslides (Kargel et al. 2016) to several environmental factors, including normalized burn ratio (NBR) derived by Landsat 7 from 2003 to 2015, using logistic regression approach
  - Potential explanatory variables:

Variable	Abbrev.	Data Source	Spatial Res	Time	Summary
Normalized Burn Ratio	NBR	LANDSAT 7	30 m	2003-2015	(SWIR-NIR)/(SWIR+NIR)
Fire Occurrence	Fires	MODIS MCD45A1	500 m	2003-2015	(Fires)/(catchment)
Drainage Density	DD	ALOS 5m DEM	5 m		(str length)/(A_s)
Topographic Wetness Index *	TWI	ALOS 5m DEM	5 m		$\ln(A_s/\tan\beta)$
Sediment Transport Index *	STI	ALOS 5m DEM	5 m		$(A_s/22.3)^m (\sin\beta/0.0896)^n$
Stream Power Index *	SPI	ALOS 5m DEM	5 m		$A_s\tan\beta$
Population Density	Pop Dens	Landscan	1 km	2010	(People)/(catchment)
Height Above Nearest Drainage	HAND	ALOS 5m DEM	5 m		Vertical distance
Slope	Slope	ALOS 5m DEM	5 m		(rise)/(run)
Euclidean Distance to Streams	Eucl Str	ALOS 5m DEM	5 m		Straight line distance
Aspect	Aspect	ALOS 5m DEM	5 m		Direction of slope
Profile Curvature	Prfl Crv	ALOS 5m DEM	5 m		Parallel to dir. max slope
Plan Curvature	Plan Crv	ALOS 5m DEM	5 m		Perpindicular to max slope
Flow Accumulation	Flow Acc	ALOS 5m DEM	5 m		Accum. pixel x pixel flow
CHIRPS	CHIRPS	CHIRPS Monthly	0.05°	2003-2015	Average monthly accum.
CHIRP	CHIRP	CHIRP Monthly	0.05°	2003-2015	Average monthly accum.

A_s = surface area of catchment; β = slope in degrees; m = 0.6; n = 1.3
(Moore et al, 1988)

Case study: Nepal fire-landslide relationship

Results for *earthquake-induced* landslides:

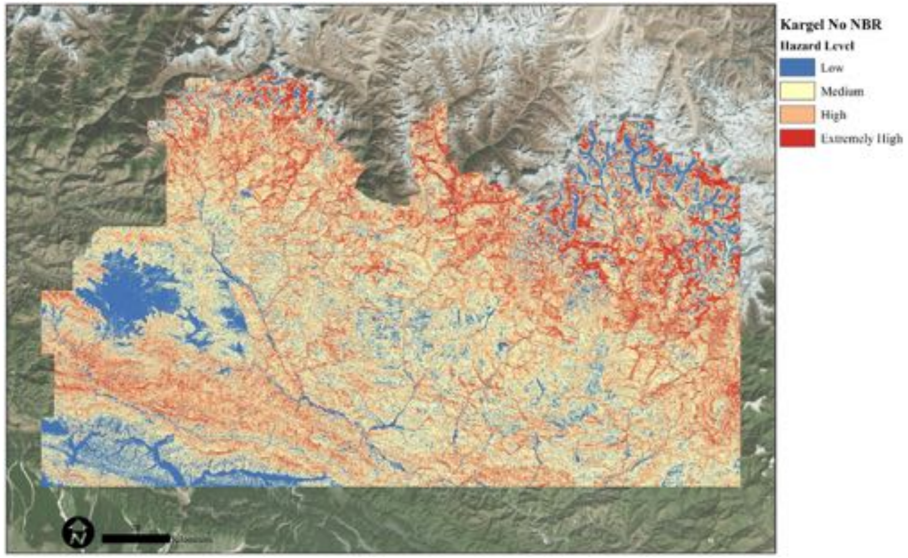
5% improvement considering NBR

Not considering NBR

$$Y = -13.007 + (0.087 * Slope) + (0.077 * CHIRP)$$

		Predicted		Accuracy
		0	1	
Observed	0	304	223	57.70%
	1	125	594	82.60%

Overall Accuracy: 72.1%

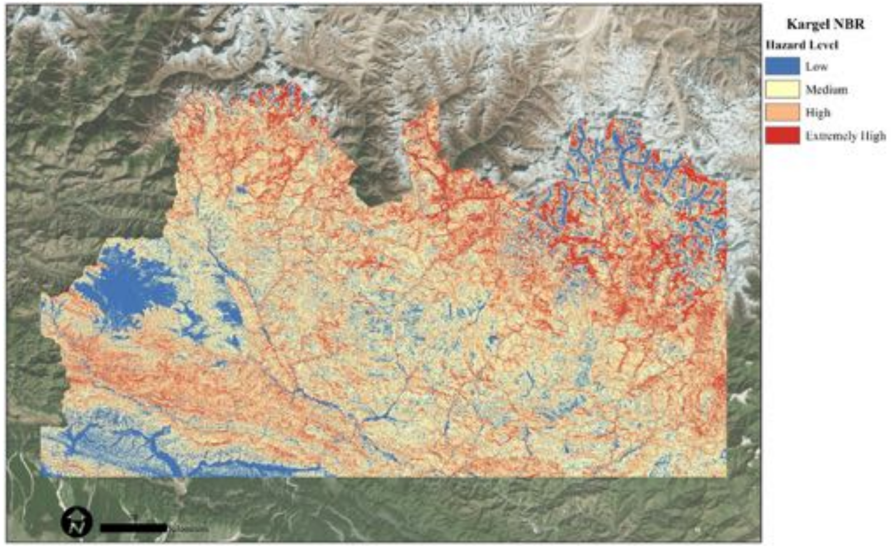


Considering NBR

$$Y = -11.945 + (0.082 * Slope) + (0.079 * CHIRP) + (15.394 * NBR)$$

		Predicted		Accuracy
		0	1	
Observed	0	363	211	63.20%
	1	118	601	83.40%

Overall Accuracy: 77.3%



Case study: Nepal fire-landslide relationship

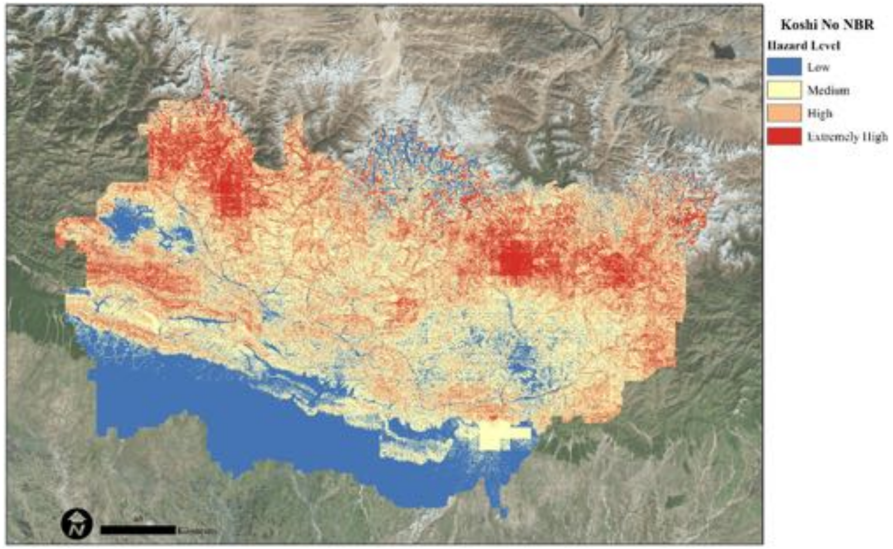
Results for *rainfall-induced* landslides: negligible difference considering NBR

Not considering NBR

$$Y = -1.203 + (0.044 * Slope) + (0.001 * CHIRP)$$

		Predicted		Accuracy
		0	1	
Observed	0	564	426	57.00%
	1	378	613	61.90%

Overall Accuracy: 59.4%

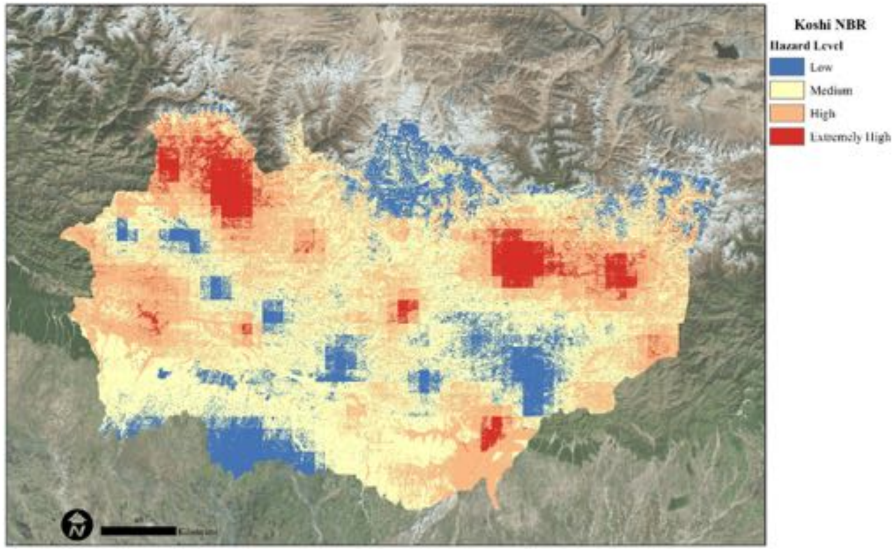


Considering NBR

$$Y = -0.856 + (4.821 * NBR) + (0.047 * Slope) + (0.005 * CHIRP)$$

		Predicted		Accuracy
		0	1	
Observed	0	591	399	59.70%
	1	381	610	61.60%

Overall Accuracy: 60.6%



Case study: Nepal fire-landslide relationship

Known limitations

- Rainfall-induced case
  - Exact landslide dates unknown; therefore, cannot test timing of explanatory variables
- Earthquake-induced case
  - Only considered one major triggering event (2015 Gorkha earthquake)
- Given unknown specific dates of most landslides in study set, we had to consider burning over a long period of time (versus single burn events)
- Further data collection on *timing and location* of burning, trigger factors (e.g., rainfall, earthquakes), and landslide events could shed more light on fire-landslide relationships

For more, see Reeves (2017): https://ntrs.nasa.gov/search.jsp?R=20170001625

CEOS Landslide Pilot

Main goals

To demonstrate the **effective exploitation** of Earth observations (EO) data and technologies to **detect, map and monitor landslides and landslide prone hillsides**, in different physiographic and climatic regions.

To apply satellite EO across the **cycle of landslide disaster risk management**, including preparedness, situational awareness, response and recovery with a distinct multi-hazard focus on cascading impacts and risks.

- Co-leads
  - **Dr. Dalia Kirschbaum**, NASA Goddard Space Flight Center, Maryland, USA
  - **Dr. Jonathan Godt**, Landslide Hazards Coordinator, U.S. Geological Survey, Colorado, USA
  - **Dr. Jean-Philippe Malet**, School and Observatory of Earth Sciences, University of Strasbourg, France
  - **Dr. Sigrid Roessner,** GFZ German Research Centre for Geosciences, Germany

CEOS Landslide Pilot

Three objectives (2016-2019):

1. Establish effective practices for merging different Earth Observation data (e.g. optical and radar) to better monitor and map landslide activity over time and space.
2. Demonstrate how landslide products, models, and services can support disaster risk management for multi-hazard and cascading landslide events.
3. Engage and partner with data brokers and end users to understand requirements and user expectations and get feedback through the activities described in objectives 1-2.

Two main focus regions: Nepal and the Pacific Northwest United States, including Washington and Oregon.

Plans for the experimental regions are still in development, but include: Southeast Alaska, China, the Caribbean (Haiti and Lesser Antilles), Peru, and Indonesia.

http://ceos.org/ourwork/workinggroups/disasters/landslide-pilot/

Areas for collaboration

SERVIR

- CEOS Landslides Pilot – Earth observations focus

- SERVIR: ADPC and Hub Consortium members are conducting additional consultations and needs assessments with stakeholders in the region to design future services. Are there ways to collaborate with other international technical institutions to collectively address landslide risk management?

- We are interested in feedback and finding ways to connect research and applications to broader NASA resources, including future:
    - NISAR – NASA-ISRO Synthetic Aperture Radar mission
    - SWOT – Surface Water Ocean Topography mission
    - Landsat 9

- AGU Fall Meeting 2017 sessions NH018: Landslide dynamics: hazard and risk assessment, triggering, modeling, in-situ observations, and remote sensing: **https://agu.confex.com/agu/fm17/preliminaryview.cgi/Session23681**

Thank you